Impatience, International Competitiveness, and Political Constraints

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Abstract

In this paper we present a model that describes how historical political constraints by themselves, or in combination with a sufficient degree of impatience, may be the cause of bankruptcy in some industries when a closed economy is opened to foreign competition. The model assesses the behavior of two types of firms, impatient and patient, which may or may not adopt foreign technology. The costs involved are not only economic but also political. These political costs are, nonetheless, measured in monetary terms. At some moment, which depends on the political constraints, a third firm enters the market, the foreign one. Depending on the national firms' degree of impatience and the costs associated with political constraints, Nash equilibria, in which one or even both firms—at the moment the economy is opened—have to shut down, exist. All these strategies result to be subgame perfect equilibrium. Further, as a by-product, our results shed new light on the topic of temporary protection: The degree of impatience, by itself, my be the reason of why temporary protection may o may not fail to induce firms to adopt advanced technologies, even if the threat of liberalization is credible; furthermore, if both firms are sufficiently patient, both firms adopt the new technology and temporary protection results to be operative in order to maximize social

welfare, so this equilibrium pass the "renegotiation-proof" criterium (along the equilibrium path).

1 Introduction

Historical evidence suggests that protectionist trade policies are often the result of a complex interaction between unions, firms, and the government. When a new labor-saving and cost reducing technology appears in the international scenario, these three actors may find themselves better off in the short run by maintaining the technology employed by the industry unchanged. This is the case when specific economic, financial, and political conditions, make them face as an alternative: unemployment, widespread bankruptcies, and social unrest. Yet every time the decision to change the technology and modernize the industry is postponed, the problem for the future worsens. If, at a given moment, the status quo was maintained for fear of unemployment and of firms' bankruptcies, as the gap between the technology used by the domestic industry and that in the industry's leaders elsewhere in the world widens, the danger of widespread unemployment and bankruptcies in the industry only increases. Thus, when the decision to modernize the industry and open up the economy is finally taken the industry is hard hit.

The history of the Mexican textile industry closely fits this description of events as is shown in Gómez-Galvarriato (2001). The comparison of production costs c. 1911 of one of the most modern and productive firms (the Compañía Industrial Veracruzana S.A.), with its international counterparts suggest that by that time the firm could compete with English cloth prices (although not with American cloth prices). Yet as time went by its competitive standing deteriorated as a result of legally binding industry wide collective contracts that hindered the firm from adopting new technology. The first "wage-list" was signed by firms' and workers' representatives in 1912. Yet it did not become legally binding until 1927 when as a result of the Convention of Workers and Industrialists of 1925-27, a collective contract was agreed with basically the same technical features as that of 1912. This collective contract fixed the maximum number of machines per worker and established specific wages-per-piece. Under these conditions, industrialists had no incentive to introduce better machinery because it would not enable them to reduce labor costs, since wages-per-piece and the workers-per-machine had to remain invariable. It set, for example, the maximum number of looms per weaver to 6, when using Nortrhop automatic looms a weaver could tend 20. It also required that the companies maintained fixed the number and type of jobs they provided. The 1925-27 Convention agreements may be understandable under the circumstances of worldwide depression in the textile industry. Nevertheless, the precepts adopted were ratified over and over again, without any changes until at least 1951, and until 1972 with few modifications. It was not until 1994, that the industry-wide collective contract in this industry was abolished. Company documents tell on the difficulties firms faced to install modern machinery, as a result of these regulations, making it many times simply impossible. These agreements were, of course, paralleled by rises in tariffs that the government carried out in order for the status quo to prevail. When tariffs were reduced after 1985 few of these firms survived.

Whereas the case of the Mexican spinning and weaving industry may be an extreme example of a sector institutionally tied down in order not to modernize, we believe this story is not exceptional, but a pattern experienced, in a lesser or greater degree, by several industries in many of the developing countries which have recently opened-up their economies. Ana Revenga's (1997) study of the Mexican manufacturing during 1984-90 period indicates that the 1985-87 trade liberalization episode affected firm-level employment and wages through several channels. It shifted down the industry product and labor demand. This in itself may have accounted for a 3%-4% decline in real wages on average (and for as much as 10%-14% decline in the more affected industries). Moreover, trade reform also reduced the rents available to be captured by firms and workers. This had an additional negative effect on firm-level employment and wages.

Several papers have addressed the question of why protectionist trade policies have failed to serve as an instrument to provide time and resources to firms to undertake cost-reducing investments that would eventually enable them to compete internationally. Their argument is based on the idea that governments are unable to credibly precommit to the unconditional elimination of protection, and thus protection generates a trade-off for the firm. "If during the program, the firm does not invest sufficiently in cost reductions, then it gains a renewal of future protection, and it saves the opportunity cost of capital. It loses, however, the benefits derived from cost reductions. If, at the margin, the gains are greater than the losses, then the firm will inevitably choose not to invest sufficiently" (Tornell, 1991). Temporary protectionist programs are thus "time inconsistent". Staiger and Tabellini (1987) have shown that an optimal trade policy may be time inconsistent, and that a suboptimal but time-consistent policy involves an excessive amount of protection, and that when protectionist policies are time inconsistent tariffs may dominate production subsidies. Matsuyama (1990) has also found dynamic inconsistency of optimal temporary protection by examining whether or not there exists a sequence of credible government threats to liberalize in the future which would induce the firms to invest as a sub-game perfect equilibrium. Although such an equilibrium exists, it fails to pass the "renegotiation-proof" criterium and thus time-inconsistency results. Tornell (1991) shows that "investment-contingent subsidies" do not eliminate time inconsistency in protectionist programs. Wright (1995) shows the time inconsistency persist even when the firm effort and costs are publicly observable. These papers suggest that a third party such as the GATT or an international treaty is necessary to make the government's threat credible and thus enable a temporary protection policy to be effective in terms of forcing the firms to invest in new technology.

In this paper we address the issue of why firms may choose not to invest in new technology even when the threat of liberalization is credible or, in other words, they have a perfect foresight of when they will face foreign competition. We suggest a theoretical approach, based on game theory, in order to describe how historical political constraints by themselves, or in combination with a sufficient degree of impatience, may be the cause of bankruptcy in some industries when a closed economy is opened to foreign competition.

The rest of the paper is organized as follows. Section II lays down the model. Section III discusses the results of the model. Finally Section IV concludes. All proofs are given in the Appendix.

2 The model

The general set-up.

Time is discrete and the horizon is infinite. In the economy, at the outset, there are two firms, one impatient and one patient, characterized by their discount factors $0 < \beta^I < \beta^P < 1$ respectively. These two firms are the players of the gahof the market are common knowledge. The foreign firm enters the market at the moment the government opens the economy. One comment: A firm can only face costs at each period if they produce (sell) strictly positive quantities, implying that the credits are implicitly introduced into the costs that we define below. A warning. Our model cannot be thought as a repeated game, as stage by stage the game's structure changes.

The payoff functions and strategies.

Informally, the game is such that, in each period $t \geq 0$, the two national firms choose to adopt or not to adopt the new and compete à la Cournot in each period. They will then maximize, at time zero, the discounted sum of the time-period profits according to the costs and the corresponding discount factors. We will define, therefore, an Extensive Game with perfect information and simultaneous moves (see, Osborne and Rubinstein 1994). Formally, the set of players is $\{I, P\}$, where I stands for the impatient firm and P for the patient firm. Let denote by A the set $\{N, T\}$ where N stands for the action *'not to change the actual technology'*, and T stands for the action *'to change the actual technology.'* That is, if a firm $i \in \{I, P\}$ at $t-1$ is facing costs according to some technology (the foreign or the national one), if that firm at t decides N, it means that it has decided —for this period t—to continue with the technology that was using at $t-1$ and, obviously, the action T means exactly the opposite. The set of histories H is given as follows. First we define $A = \{N, T\} \times \{N, T\}$ and then $H = \{\varnothing\} \{(a_t)_{t=0}^{\infty} \, | a_t \in A, \, t \geq 0\}$. Given $(a_t^I, a_t^P) \in \{N, T\} \times \{N, T\}$, we use the interpretation that, for any t the first coordinate of the pair (a_t^I, a_t^P) is the action chosen by the firm I at period t and, similarly, the second coordinate is the action chosen by the patient firm at that period. The player function $\tilde{P} : H \to \{I, P\}$ is given by $\tilde{P}(h) \in \{I, P\}$ for all $h \in H$. Therefore, the set of strategies for the player $i \in \{I, P\}$ is given by $S^i = S = \left\{ \{s_h\}_{h \in H} \, | s_h \in \{N, T\}, \text{ for all } h \in H \ \right\}$. Logically, given a profile of strategies $\left(s^I, s^P\right) \in S \times S$, this pair determines a path that is actually played, according to those strategies, of the form $\left\{ \left(a_t^I, a_t^P\right) \right\}_{t=0}^{\infty}$, with $a_t^i \in \{N, T\}$ for all $t \geq 0$, which in turn determines a sequence of costs of the form $\left\{ \left(C_t^I, C_t^P\right) \right\}_{t=0}^{\infty}$. Now, if the firms adopt a profile of strategies $\left(s^P, s^I\right) \in S \times S$, and the corresponding sequence of costs is given by $\left\{ \left(C_t^I, C_t^P\right) \right\}_{t=0}^{\infty}$, and the foreign firm enters the market at $\bar{t}$, the payoff function of the firm i is given by

$$\Pi^i(\left(s^i, s^j\right)) = \sum_{t=0}^{\bar{t}-1} (\beta^i)^t \pi^i(C_t^i, C_t^j) + \sum_{t=\bar{t}}^{\infty} (\beta^i)^t \pi^i(C_t^i, C_t^j, C^F) \tag{1}$$

with $i, j = I, P$, where $\pi^i(C_t^i, C_t^j)$ is the Cournot profit of firm $i \in \{I, P\}$ at time $t < \bar{t}$, if the respective costs for that period are C_t^i and C_t^j, and similarly

$\pi^i(C_t^i, C_t^j, C^F)$ is the Cournot profit of firm i at time $t \geq \bar{t}$, if the national firms face C_t^i and C_t^j and the foreign firm faces C^F, as mentioned before.

Remark 1 *According to our assumption that there are no credits, if for a given profile of strategies* $\left(s^I, s^P\right)$*, the corresponding sequences of costs* $\left\{\left(C_t^I, C_t^P\right)\right\}_{t=0}^{\infty}$ *is such that a firm* $i \in \{I, P\}$ *produces no positive quantities (or, equivalently, if it does not have positive time-period profits)*[1] *of the good for* $t \geq \tilde{t}$ *for some for some* $\tilde{t} \geq 0$*, then we say that the corresponding firm shuts down and leaves the market at time* $t = \tilde{t}$*. Similarly, and once again in accordance with the assumption that there are no credits, if a profile of strategies* $\left(s^I, s^P\right)$ *is such that for a firm* $i \in \{I, P\}$*, the strategy* s^i *prescribes at some* t *the adoption of the new technology, but the time period-profits are zero at the periods in which the new technology is being adopted (from* t *on), then we say that technology is not active for that firm, that is, the corresponding firm does not have the real possibility to use the new technology, just because, in fact, it has not covered the costs that we describe below. Therefore, in this last situation, we assume that if the correspondign firm decides once again to adopt the new technology in later periods, it will have to face the costs as it were not paid anything before.*

The costs.

The firms may use the extant national technology, characterized by its constant marginal cost C^N in each period, or they may adopt the new foreign technology, characterized by C^F, which is the cost that the foreign firm that owns it has to face. If the national firms want to adopt the new technology, they still have to face not only C^F but also some additional economic and political costs, which are described below.

- *The economic costs.*
  The extra economic costs are exogenously given and defined by a decreasing finite sequence C_0^e, C_1^e,...,C_n^e ($C_t^e > C_{t+1}^e$ for all $0 \leq t \leq n-1$), where C_n^e is the permanent cost that the national firm adopting the new technology has to pay to the owner of said technology. In this way, we capture the idea that at the beginning the economic costs are high but decrease over time until stabilizing at the level C_n^e, which represents

[1] See our lemma 1 in the Appendix.

the royalty paid to the owner of the foreign technology.[2] Hence, if at $t = \bar{t}$ the new technology is adopted, the economic costs paid by the firm from that moment are $C_{\bar{t}\,+t} = C^F + C_t^e$ for all $0 \leq t \leq n$, and the firm faces $C^F + C_n^e$ from $t = \bar{t}\,+n$; that is, $C_t = C^F + C_n^e$ for all $t \geq \bar{t}\,+n$. In other words, if the foreign technology is adopted at $t = \bar{t}$, the sequence of costs that the firm faces is given by $\{C_t\}_{t=0}^{\infty}$, where $C_t = C^N$ for all $0 \leq t < \bar{t}$, $C_t = C^F + C_t^e$ for all $\bar{t} \leq t < \bar{t} + n - 1$, and $C_t = C^F + C_n^e$ for all $t \geq \bar{t} + n$.
The time length $n + 1$ is the number of periods that a national firm needs to completely install the new technology. After this, the firm only has to pay the natural cost (C^F) plus the royalty (C_n^e). It is reasonable to think of these costs as decreasing, since normally installing a new technology causes some exceptional costs at the beginning. We assume that $n > 0$. If $n = 0$, the two firms install the new technology at $t = 0$, there is no trade off between to install or not to install.

- *The political costs.*

In this paper we do not model the political process that leads to protection. We simply model this protection by assuming that there are some costs legally imposed over a firm if it decides to adopt a foreign technology. We call those costs *political costs*, which are exogenously given and defined by a possibly infinite sequence $\{C_t^p\}_{t=0}^{l}$ ($l \leq \infty$). Each C_t^p represents the extra cost that the firm has to pay if it adopts the new technology at time t, but once and for all, due to, for instance, the fact that the firm may have to dismiss some workers that are not useful anymore. These costs depend on negotiations between the firms, the government, and the trade unions. The more powerful the trade unions are, the larger these costs would be. It would be reasonable to assume that those costs are increasing because as the gap between the domestic and the foreign technology widens it is likely that more workers would be redundant when the foreign technology is adopted. Nonetheless, without that assumption, the model can be used to as-

[2] An alternative interpretation for the permanent cost C_n^e can be given: The owner of the technology is the person who produces it, and only this person. Therefore, C_n^e may represent his profits, if we understand that he is selling not the new technology but the strategic elements to use it. These elements cannot be produced by anyone but the owner; thus, the buyer cannot develop that new technology.

sess situations under which those costs can become constant or even decreasing —at least temporarily—, as it is the case in some countries in Europe, Spain, for example. [3]

The role of the government

The government decides the period at which the economy opens, although it is exogenously given. At that moment, the foreign firm enters the market. As for the domestic firms, for simplicity, we assume that when the foreign firm enters, faces a constant marginal cost each period. Given this last assumption, without loss of generality, we set that cost at C^F. Let denote by t^g the period time at which the economy opens. As it has been expressed, the government also plays a role, together with the firms and the trade unions, as a party in the negotiations that determine the political costs that the firms face if they adopt the new technology.

Technical assumptions

Some fundamentals of the economy satisfy the following general conditions:[4]

A1 $C^N < a$.

This is the minimal hypothesis to assume in order to make sensible the maximization problem of the firms: It simply implies that it is possible to produce positive quantities of the good.

A2 $a - C^N \leq \frac{a-C^F}{2}$

This means that the foreign technology not only is more efficient than the national one but also that the national one is not competitive, in the sense that it only can produce zero quentities of the good, if it competes face to face with the foreign technology. Notice that A2 implies that $C^F < C^N$.

A3 A3.1) $C^N < C^e_t + C^F < a$ for all $0 \leq t \leq n-1$; A3.2) $\frac{a+C^N}{2} > C^e_0 + C^p_t + C^F$ for all $t < t^g$; A3.3) $\frac{C^F+a}{2} > C^e_n + C^F$.

[3]In Spain, the labor market has been historically very rigid, being this, perhaps, one of the 'causes' of very high rates of unemployment. In any case, lately, the labor market is more flexible than in the past, allowing for temporal job and, because of this, lowering the political cost, in our broad sense.

[4]In order to obtain the formal justification of the assumptions' interpretations, we refer to the lemma 1 in the Appendix

This assumption capture the following idea: The new technology is more costly–but not too costly– than the national one at the beginning (A3.1), it can be installed (A3.2) but, at some moment, once it is completely installed, becomes not only more efficient than the national one but also, if it used by the two national firms, it is capable produce positive quantities even when the economy is already opened (A3.3). We set that moment at $t = n$ just for simplicity. "No results change without this simplification. Nevertheless, it is reasonable to think of that the new technology, from the point of view of the national firms, becomes more efficient at the moment the costs stabilize." Notice that, A2 and A3.1 implies that $a - (C_t^e + C^F) < \frac{a-C^F}{2}$ for all $0 \leq t \leq n-1$ and, hence, we will have that the only way to survive, after the economy is opened, is to have the new technology completely installed. Also, observe that A2 and A3.3 imply that $C^N > C_n^e + C^F$.

Therefore, the extensive game with perfect information that resumes our model is given by $\Gamma = \left\langle \{I, P\}, H, \tilde{P}, (\Pi^i)_{i \in \{I,P\}} \right\rangle$.

3 The Results

For the sake of clarity, we first give the intuition of a result and then we announce formally the corresponding theorem. In this section, no proofs are presented. All formal proofs are given in the Appendix.

The first result responds to the following intuition. If the economy opens too early —this is formally expresed by imposing the condition $t^g < n$— , or if the political costs are too high at the beginning —this is formally expresed by the condition $a - (C_n^e + C^F) < C_t^p$ for all $t \leq t^g - 1$, both firms, independently of their degree of impatience, decide not to adopt the foreign technology, because they cannot afford the total costs. At the moment the foreign firm enters the market, both national firms have to shut down, and those decisions, if revised in the future, are not changed (there are no advantages in do it so), given that there are no credit market opportunities. Furthermore, at any possible history, the decisions taken are at least as good as any other possibility, so there are no 'non-credible promises.'Formally:

Theorem 1 *If (1.1) $t^g < n$ (the government opens the economy too early), or (1.2) if $t^g \geq n$, but $a - (C_n^e + C^F) < C_t^p$ for all $t \leq t^g - 1$ (the political costs are too high at the beginning), then there is a subgame perfect Nash equilibrium, given by $(s^P, s^I) = \left(\{s_h(N,1)\}_{h \in H}, \{s_h(N,1)\}_{h \in H}\right)$, where*

$s_h(N,1) = N$, *if* $h = \left\{(a_l^I, a_l^P)\right\}_{l=0}^{t} \in H$ *is such that if the technology that was in use at* t *was the national one, and* $s_h(N,1) = T$ *in the other case. That is, both firms choose the same strategy in which, at any history they decide to use the national technology. Therefore, both firms shut down at the moment the economy opens, that is, at* $t = t^g$.

The second result is in correspondence with the following intuition. Even if the political forces are in a minimal degree of coordination, in the sense that by themselves are not the cause of bankruptcy, a sufficient degree of impatience in a firm, makes the corresponding firm to ignore future possible profits, and then to decide not to adopt the new technology at the appropriate moment, so at the moment the foreign firm enters the market, the national firm shuts down. If that firm would like to adopt the new technology later, this technology is not affordable anymore, because of the presence of the foreign firm. On the other hand, if it were the case that one firm is patient enough and the other is sufficiently impatient, then the patient one adopts the new technology at the outset, and the other decides not to adopt the new technology. Also, if both firms are sufficiently impatient, both firms decide not to adopt the new technology, and both shut down at the moment the economy opens. Also, if these decisions are revised in future times, are not changed, because there are no advantages in do it so and, furthermore, once again, at any possible history, the decisions taken are at least as good as any other possibility, so there are no 'non-credible promises.'

For the sake of the exposition, we will now explain and define the strategies of the firms. We will denote by $\left\{s_h^I(N,2)\right\}_{h\in H}$ the strategy of the impatient firm. On the other hand, the patient firm that adopt the new technology will choose a strategy that we denote by $\left\{s_h^P(T)\right\}_{h\in H}$. Informally, those strategies are described as follows. $\left\{s_h^P(T)\right\}_{h\in H}$ is such that at any history at which either the new technology is already installed or it is possible to finish to install it, the patient firm adopt the new technology, otherwise it chooses not to adopt the new technology. $\left\{s_h^I(N,2)\right\}_{h\in H}$ is such that at any history at which the new technology is already installed or it is possible to finish to install one period later, it prescribes to continue with the new technology; otherwise it prescribes not to adopt the new technology if the technology in use the previous period was the national one, and to continue with national one in the other case.

In order to formally describe these strategies, the following definitions are convenient:

Definition 1 *Suppose that* $t^g \geq n$ *and* $\frac{a-2(C_0^e+C^F)+(C^F+C_n^e)}{2} > C_t^p$ *for all* $t \leq t^g - 1$. *Then: D1.1) We will say that a history* $\left\{(a_l^I, a_l^P)\right\}_{l=0}^t \in H$, *for the firm* P, *is such that the new technology 'is possible to finish to install it from the beginning, independently of the* I*'s strategy' if* $a_0^P = T$, $a_l^P = N$ *for all* $0 < l \leq t$, $a_l^I \in \{N, L\}$ *for all* $0 \leq l \leq t$ *and* $t < n$*; D1.2) Similarly, we will say that a history* $\left\{(a_l^I, a_l^P)\right\}_{l=0}^t \in H$, *for the firm* P, *is such that the new technology is 'completelly installed from the beginning, independently of the* I*'s strategy' if* $a_0^P = T$, $a_l^P = N$ *for all* $0 < l \leq t$, $a_l^I \in \{N, L\}$ *for all* $0 \leq l \leq t$ *but* $t \geq n$. *Notice that, in the first definition, the corresponding sequence of costs is* $\left\{(C_l^I, C_l^P)\right\}_{l=0}^t$ *with* $C_0^P = C_0^e + C^F + C_0^p$ *and* $C_l^P = C_l^e + C^F$*for all* $t \geq l \geq 1$*; in the second definition, the sequence of costs is such that* $C_0^P = C_0^e + C^F + C_0^p$, $C_l^P = C_l^e + C^F$*for all* $n-1 \geq l \geq 1$, *and* $C_l^P = C_n^e + C^F$ *for all* $n \leq l \leq t$.

Definition 2 *Suppose that* $t^g \geq n$ *and* $\frac{a-2(C_0^e+C^F)+(C^F+C_n^e)}{2} > C_t^p$ *for all* $t \leq t^g - 1$. *Then: D2.1) We will say that a history* $\left\{(a_l^I, a_l^P)\right\}_{l=0}^t \in H$, *for the firm* P, *is such that the new thechnology is ' possible to finish to install it but not from the beginning, independengly of the* I*'s strategy' if the corresponding sequence of costs satisfies that there is* l_1 *such that* $0 < l_1 < t$, $l_1 + n \leq t^g$, $t < l_1 + n$, $C_{l_1}^P = C_0^e + C_{l_1}^p + C^F$, *and* $C_{l_1+k}^P = C_k^e + C^F$ *for all* k *such that* $l_1 + k \leq t$*; D2.2) Similarly, we will say that a history* $\left\{(a_l^I, a_l^P)\right\}_{l=0}^t \in H$ *is such that the firm* P *'has decided to completelly install the new technology but not from the beginning, independengly of the* I*'s strategy' if* $a_l^I \in \{N, L\}$ *for all* $0 \leq l \leq t$, *and if* $\left\{(C_l^I, C_l^P)\right\}_{l=0}^t$ *is the corresponding sequence of costs, then there is* l_1 *such that* $0 < l_1 < t$, $l_1 + n \leq t^g$, $l_1 + n \leq t$, $C_{l_1}^P = C_0^e + C_{l_1}^p + C^F$, $C_{l_1+k}^P = C_k^e + C^F$ *for all* $1 \leq k \leq n-1$, *and* $C_l^P = C_n^e + C^F$ *for all* $t \geq l \geq l_1 + n$.

Now we define the following subsets of histories .

$$H_0^P = \{h \in H \,|h \text{ satisfies D1.1 or D1.2}\}, \tag{2}$$

which represents all the histories such that the patient firm decides, from the beginning to the time period corresponding to the history, to adopt the new technology;

$$H_1^P = \{h \in H \,|h \text{ satisfies D2.1, or D2.2 }\}, \tag{3}$$

which represents the set of all histories such that the new technology is already installed, but not from the beginning, and it is under use from the moment it was installed to the time period of the history in question.

The same definitions apply to the firm I, just changing P for I where it proceeds.

The strategies:

$$s_h^I(N,2) =$$
$$\left\{ \begin{array}{l} s_h^I(N,2) = N \text{ if } h = \emptyset \\ s_h^I(N,2) = T \text{ if } h = \left\{(a_l^I, a_l^P)\right\}_{l=0}^{t} \in H_0^I \text{ and } t < n-1 \\ s_h^I(N,2) = N \text{ if } h = \left\{(a_l^I, a_l^P)\right\}_{l=0}^{t} \in H_0^I \text{ and } t \geq n-1 \\ s_h^I(N,2) = T \text{ if } h = \left\{(a_l^I, a_l^P)\right\}_{l=0}^{t} \in H_1^I \text{ and } t < l_1+n-1 \\ s_h^I(N,2) = N \text{ if } h = \left\{(a_l^I, a_l^P)\right\}_{l=0}^{t} \in H_1^I \text{ and } t \geq l_1+n-1 \\ s_h^I(N,2) = T \text{ if } h \neq \emptyset,\ h = \left\{(a_l^I, a_l^P)\right\}_{l=0}^{t} \notin H_0^I \cup H_1^I \text{ and } C_t^I \neq C^N \\ s_h^I(N,2) = N \text{ if } h \neq \emptyset,\ h = \left\{(a_l^I, a_l^P)\right\}_{l=0}^{t} \notin H_0^I \cup H_1^I \text{ and } C_t^I = C^N \end{array} \right\} \tag{4}$$

and

$$s_h^P(T) =$$
$$\left\{ \begin{array}{l} s_h^P(T) = T \text{ if } h = \emptyset \\ s_h^P(T) = N \text{ if } h = \left\{(a_l^I, a_l^P)\right\}_{l=0}^{t} \in H_0^P \cup H_1^P \\ s_h^P(T) = T \text{ if } h \neq \emptyset,\ h = \left\{(a_l^I, a_l^P)\right\}_{l=0}^{t} \notin H_0^P \cup H_1^P,\ C_t^P = C^N \text{ and } t+n \leq t^g - 1 \\ s_h^P(T) = N \text{ if } h \neq \emptyset,\ h = \left\{(a_l^I, a_l^P)\right\}_{l=0}^{t} \notin H_0^P \cup H_1^P,\ C_t^P = C^N \text{ and } t+n \geq t^g \\ s_h^P(T) = T \text{ if } h \neq \emptyset,\ h = \left\{(a_l^I, a_l^P)\right\}_{l=0}^{t} \notin H_0^P \cup H_1^P \text{ and } C_t^P \neq C^N \end{array} \right\} \tag{5}$$

Analogous definitions apply changing I for P and P for I in (4) and (5) respectively, where it proceeds.

Theorem 2 *Suppose that $t^g \geq n$, the finite sequence $\{C_l^p\}_{l=0}^{t^g-1}$ is non decreasing and, $\frac{a-2(C_0^e+C^F)+(C^F+C_n^e)}{2} > C_t^p$ for all $t \leq t^g - 1$, then: (2.1) If the firm I is sufficiently impatient (β^I is small enough) and the other firm P is sufficiently patient (β^P is large enough), then $(s^I, s^P) = (\left\{s_h^I(N,2)\right\}_{h\in H}, \left\{s_h^P(T)\right\}_{h\in H})$ is a subgame perfect Nash equilibrium; (2.2) If both firms are sufficiently impatient, then $(s^I, s^P) = (\left\{s_h^I(N,2)\right\}_{h\in H}, \left\{s_h^P(N,2)\right\}_{h\in H})$ is a subgame perfect Nash equilibrium; (2.3) If both firms are sufficiently patient, then $(s^I, s^P) = (\left\{s_h^I(T)\right\}_{h\in H}, \left\{s_h^P(T)\right\}_{h\in H})$ is a subgame perfect Nash equilibrium.*

Some remarks in relation to the results obtained are in order.

Remark 2 *The requirement that "the finite sequence $\{C_l^p\}_{l=0}^{t^g-1}$ is non decreasing" is too strong (albeit appealing). For s^i be $\{s_h^i(T)\}_{h\in H}$ (with $i \in$*

$\{I, P\}$) in any of the equilibria given in the theorem 2, it is enough (and necessary) to require that $\left(\pi^i(C_n^e + C^F, \cdot) - \pi^i(C^N, \cdot)\right) +$
$\left(\pi^i(C_0^e + C_0^p + C^F, \cdot) - \pi^i(C_0^e + C_l^p + C^F, \cdot)\right) \geq 0$ for all $l \leq t^g - 1$. This last condition is crearly satisfied if $\{C_l^p\}_{l=0}^{t^g-1}$ is non decreasing and, even less demanding, if $C_l^p > C_0^p$ for all $l \leq t^g - 1$.*

Remark 3 *When reading the proofs given in the Appendix, and taking into acount the prevous remark, it is not difficult to see that other equilibria exist. Only think of in situations where the condition "$(\pi^i(C_n^e + C^F, \cdot) - \pi^i(C^N, \cdot)) + (\pi^i(C_0^e + C_0^p + C^F, \cdot) - \pi^i(C_0^e + C_l^p + C^F, \cdot)) \geq 0$ for all $l \leq t^g - 1$" is not satisfied. In such situations, that firm (the patient one) installs the new technology, but not at the beginning (we remit to our footnote 3). We omit the formal presentation of these possible equilibria since they have the same flavor as the case presented in the theorem 2.*

Remark 4 *If, in the theorem 2, we replace the condition $\frac{a-2(C_0^e+C^F)+(C^F+C_n^e)}{2} > C_t^p$ for all $t \leq t^g - 1$, for the condition $\frac{a-2(C_0^e+C^F)+(C^F+C_n^e)}{2} > C_0^p$ and $\frac{a-2(C_0^e+C^F)+(C^F+C_n^e)}{2} < C_t^p$ for all $0 < t \leq t^g - 1$, the equilibria commented in the previous remark disappear. In words, if a firm does not install the new technology at $t = 0$, it will never be again profitable to install it, independently of the correspondent degree of patience. This result heavily highlight the path-dependence problem that is present in the economic phenomenon described in this paper: A given decision in the past, implies irreversible consequences over the present and the future.*

Remark 5 *It is important to notice that the equilibrium given in (2.3) of the theorem 2 can be part of a subgame perfect Nash equilibria in an extended model in which the government is a player, even considering various different situations.[5] Indeed, take that equilibrium and consider the following scenarios:*

[5]Given the potential richness and complexity of the suggested extended models, a complete and detailed treatment of those medels is left for future reaserch. Not only it is necessary to modify the notation of the model (strategies of the firms, histories, and player functions), but also it may be the case that some of the equilibria obtained here will not be subgame perfect Nash equilibrium in the corresponding extended model. For intstance, it may be the case that there will be necessary some kind of coordination between the firms. Also, notice that here we only present now what the government would do along the equilibrium path.

S1) Suppose that the government maximizes the consumer's surplus (a demagogic government, let's say), therefore the value of the welfare of the society at time t^g *if the economy is opened is* $W(L,(\{s_h^I(T)\}_{h\in H},\{s_h^P(T)\}_{h\in H}),D) = \frac{1}{2}\left[2\left(\frac{a-2(C_n^e+C^F)+C^F}{4}\right)+\left(\frac{a-3C^F+2(C_n^e+C^F)}{4}\right)\right]^2$ *and in the other case is* $W(NL,(\{s_h^I(T)\}_{h\in H},\{s_h^P(T)\}_{h\in H}),D) = \frac{1}{2}\left[2\left(\frac{a-(C_n^e+C^F)}{3}\right)\right]^2$*; now, observe that* $\lim_{(C^F,C_n^e)\to(0,0)} W(L,(\{s_h^I(T)\}_{h\in H},\{s_h^P(T)\}_{h\in H}),D) = (\frac{1}{2})(\frac{9}{16})a^2$ *and* $\lim_{(C^F,C_n^e)\to(0,0)} W(NL,(\{s_h^I(T)\}_{h\in H},\{s_h^P(T)\}_{h\in H}),D) = (\frac{1}{2})(\frac{4}{9})a^2$*; consequently, taking* (C^F,C_n^e) *small enough (and consistently with A1-A3), we have* $W(L,(\{s_h^I(T)\}_{h\in H},\{s_h^P(T)\}_{h\in H}),D) > W(NL,(\{s_h^I(T)\}_{h\in H},\{s_h^P(T)\}_{h\in H}),D)$. *Therefore, the government opens the economy at* $t=t^g$ *as promised at* $t=0$. *Notice that this scenario may be considered the most probable ammong all the possible ones: A demagogic government maximizing the probability of winning the next elections, so that the firms will be willing to think that the government will open the economy at the promised moment.*

S2) Suppose that the government maximizes the welfare of the whole society, therefore the value of the welfare of the society at time t^g *if the economy is opened is* $W(L,(\{s_h^I(T)\}_{h\in H},\{s_h^P(T)\}_{h\in H}),B) = \left\{\frac{1}{2}\left[2\left(\frac{a-2(C_n^e+C^F)+C^F}{4}\right)+\left(\frac{a-3C^F+2(C_n^e+C^F)}{4}\right)\right]^2\right\}+\left\{2\left[\left(\frac{a-2(C_n^e+C^F)+C^F}{4}\right)\right]^2\right\}+\tau\left(\frac{a-3C^F+2(C_n^e+C^F)}{4}\right)^2$ *(here, the first term is the consumer's surplus, the second term consists of the benefits of the two national firms, and the third is taxes* (τ) *times the benefits of the foreign firm), and in the other case is* $W(NL,(\{s_h^I(T)\}_{h\in H},\{s_h^P(T)\}_{h\in H}),B) = \left\{\frac{1}{2}\left[2\left(\frac{a-(C_n^e+C^F)}{3}\right)\right]^2\right\}+\left\{2\left[\left(\frac{a-(C_n^e+C^F)}{3}\right)\right]^2\right\}$*, then* $\lim_{(C^F,C_n^e,\tau)\to(0,0,1)} W(L,(\{s_h^I(T)\}_{h\in H},\{s_h^P(T)\}_{h\in H}),B) = (\frac{1}{2})(\frac{9}{16})a^2+\left[2(\frac{1}{16})+(\frac{1}{16})\right]a^2 = \frac{15}{32}a^2$ *and* $\lim_{(C^F,C_n^e)\to(0,0)} W(NL,(\{s_h^I(T)\}_{h\in H},\{s_h^P(T)\}_{h\in H}),B) = (\frac{1}{2})(\frac{4}{9})a^2+2(\frac{1}{9})a^2 = \frac{4}{9}a^2$*; therefore, taking* (C^F,C_n^e) *small enough and* τ *large enough, we have that* $W(L,(\{s_h^I(T)\}_{h\in H},\{s_h^P(T)\}_{h\in H}),B) > W(NL,(\{s_h^I(T)\}_{h\in H},\{s_h^P(T)\}_{h\in H}),B)$. *Therefore, the government opens the economy at* $t=t^g$ *as promised at* $t=0$.

4 Conclusions

The model developed in this paper suggests that even when a government can credibly precommit to open-up the economy to foreign competition and firms have perfect foresight of when that will happen, they may choose not to invest in new technology. This is the case when unions are too strong, and thus the political costs firms face when they adopt the new technology are too high, or/and when the time-period given by the government for trade liberalization is too short, even when firms are sufficiently patient. The same result arises when firms are too impatient, regardless of political costs, or the length of time-period before trade liberalization. However, when firms are patient enough and there is political coordination in terms of the relation between political costs and the time-period given before trade liberalization national firms can adopt the new technology and successfully compete with the foreign firm.

Our model, also, describes and incorporates the severe problem of path-dependency in the sense commented in the remark 4: If the political costs are increasing, as a result of the widening of the technology gap between the national and the new technology, then it is important that firms choose to adopt the new technology early, otherwise they will not be able to do it later, and will close when the foreign firm enters. It raises, additionally, the importance of credit markets given that if there are no credit opportunities, the firms must close if the conditions that they face are adverse for the adoption of the new technology. Conversely, if there are credit opportunities the firms may survive once the foreign firm enters the market even if they had not invested in the new technology earlier.

In this paper we have not included the possibility that firms' decisions to invest or not to invest may affect the time-period the government defines before liberalization as Staiger and Tabellini (1987), Matsuyama (1990) and Tornell (1991) have done. This could be an interesting extension to this paper. Our remark 5 is giving an insight of one of the possible results in this new scenario, one in which temporary protection is succefull and a good decision for a government even if it is maximazing the welfare of the whole society. However, since we consider two domestic firms instead of a monopolist firm, as Matsuyama (1990) and Tornell (1991) do, it could show the necessity of coordination between firms to follow a similar strategy in order to generate the desired response from the government.

5 Appendix

First of all, we recall some well known results in relation to Cournot Competence.

Lemma 1 *Suppose that the inverse demand function is given by* $P(Q) = a - Q$. *Then*
a)If there are two firms facing constant marginal costs C^1 *and* C^2 *that compete à la Cournot, and* $a - C^i > 0$ *for* $i = 1, 2$, *then if* (q^1, q^2) *denotes the Nash equilibrium, we have*

$$\left(q^k\right)_{k\in\{1,2\}} = \left\{ \begin{array}{l} q^i = \frac{a-2C^i+C^j}{3} \text{ if } a - C^i > \frac{a-C^j}{2} \text{ for } i,j \in \{1,2\}, i \neq, j \\ q^i = \frac{a-C^i}{2}, q^j = 0, \text{ if } a - C^j \leq \frac{a-C^i}{2} \text{ for } i,j \in \{1,2\}, i \neq, j \end{array} \right. ,$$

and the Cournot profits of the firm $ii \in \{1,2,3\}$ *is given by* $\pi^i(C^i, C^j) = \left(q^i\right)^2$ *for* $i = 1, 2$; *and*
b) If there are three firms facing constant marginal costs C^i *with* $i = 1, 2$ *and* 3 *that compete á la Cournot, then if* $\left(q^k\right)_{k\in\{1,2,3\}}$ *denotes a Nash equilibrium, we have that*

$$\left(q^k\right)_{k\in\{1,2,3\}} = \left\{ \begin{array}{l} q^i = \dfrac{a-3C^i+\sum_{j\neq i} C^j}{4} \text{ if } a - C^i > \sum\limits_{j\neq i} \frac{(a-C^j)}{3}, \text{ for } i \in \{1,2,3\} \\ \left\{ \begin{array}{l} q^i = 0, \; q^j = \frac{a-2C^j+C^k}{3}, \; \text{ if } a - C^i \leq \sum\limits_{j\neq i} \frac{(a-C^j)}{3} \\ \text{and } a - C^j > \frac{a-C^k}{2} \text{ for } j,k \in \{1,2,3\} \setminus \{i\}, \; j \neq k, \end{array} \right\}_{i\in\{1,2,3\}} \\ \left\{ q^i = \frac{a-C^i}{2}, q^j = 0 \text{ for } j \neq i, \text{ if } \frac{a-C^i}{2} \geq a - C^j \text{ for } j \neq i \right\}_{i\in\{1,2,3\}} \end{array} \right. ;$$

the Cournot profits of the firm $i \in \{1,2,3\}$ *is given by* $\pi^i(C^i, C^{-i}) = \left(q^i\right)^2$.

Proof: Routine and omitted.

For all the proofs we will use the one-stage deviation principle for infinite-horizon games (theorem 4.2, in Fudenberg and Tirole (2002)).

1 Proof of theorem 1.

1.1 The proof of (1.1).

Following Osborne and Rubinstein (1994), we introduce the following notiation. Given the extensive game form with perfect information $\Gamma =$

$\left\langle \{I,P\}, H, \tilde{P}, (\Pi^i)_{i\in\{I,P\}} \right\rangle$, if $\tilde{h} = \left\{(a_l^I, a_l^P)\right\}_{l=0}^t \in H$, then $\Gamma(\tilde{h}) = \left\langle \{I,P\}, H|_{\tilde{h}}, \tilde{P}\Big|_{\tilde{h}}, (\Pi^i|_{\tilde{h}})_{i\in\{I,P\}} \right\rangle$ will denote the subgame of Γ that follows the history $\tilde{h}$, where $H|_{\tilde{h}}$ is the set of sequences h' of actions for which $\left(\tilde{h}, h'\right) \in H$, $\tilde{P}\Big|_{\tilde{h}}$ is defined by $\tilde{P}\Big|_{\tilde{h}}(h') = \tilde{P}(\tilde{h}, h')$ for each $h' \in H|_{\tilde{h}}$ and $\Pi^i|_{\tilde{h}}$ is defined by h' is as least a good as h'' if and only if $(\tilde{h}, h')$ is as good as $(\tilde{h}, h'')$. Similarly, given a strategy s, $s|_{\tilde{h}}$ will denote the strategy that s induces in the subgame $\Gamma(\tilde{h})$, that is, $s|_{\tilde{h}}(h') = s\left(\tilde{h}, h'\right)$ for each $h' \in H|_{\tilde{h}}$.

With this notation in place, we proceed to the proof.

First notice that the profile of strategies $\left(\{s_h(N)\}_{h\in H}, \{s_h(N)\}_{h\in H}\right)$ is such that, $\Pi^i\left(\{s_h(N)\}_{h\in H}, \{s_h(N)\}_{h\in H}\right) =$
$\sum\limits_{t=0}^{t^g-1}(\beta^i)^t\pi^i(C^N, C^N) + \sum\limits_{t=t^g}^{\infty}(\beta^i)^t\pi^i(C^N, C^N, C^F) = \sum\limits_{t=0}^{t^g-1}(\beta^i)^t\pi^i(C^N, C^N) > 0$ for $i \in \{I, P\}$, since $\pi^i(C^N, C^N) > 0$ (A1 and (a) in lemma 1) and $\pi^i(C^N, C^N, C^F) = 0$ (A2 and (b) in lemma 1), and therefore both firms shut down at $t = t^g$.

Now take any history $\tilde{h} = \left\{(a_l^I, a_l^P)\right\}_{l=0}^t$ for $t < t^g - 1$. This history determines a vector of costs of the form $\left\{\left(C_l^I, C_l^P\right)\right\}_{l=0}^t$. Notice that the profile $(\{s_h(N)\}_{h\in H}|_{\tilde{h}}, \{s_h(N)\}_{h\in H}|_{\tilde{h}})$ is such that the corresponding sequence of costs that follows $\tilde{h}$ is $\left\{\left(C_l^I, C_l^P\right)\right\}_{l=t+1}^{\infty}$, where $C_l^I = C_l^P = C^N$ for all $l \geq t+1$. Therefore, the payoff of the player i from the subgame starting after the history $\tilde{h}$, given the profile of strategies $(\{s_h(N)\}_{h\in H}|_{\tilde{h}}, \{s_h(N)\}_{h\in H}|_{\tilde{h}})$, is given by

$$\Pi^i((\{s_h(N)\}_{h\in H}|_{\tilde{h}}, \{s_h(N)\}_{h\in H}|_{\tilde{h}}))|_{\tilde{h}} =$$
$$\begin{cases} \left\{\begin{array}{l} \sum\limits_{l=0}^{t}(\beta^i)^t\pi^i(C_{\tilde{t}}^i, C_{\tilde{t}}^j) + (\beta^i)^{t+1}\pi^i(C^N, C^N) + \\ \sum\limits_{l=t+2}^{t^g-1}(\beta^i)^l\pi^i(C^N, C^N) \end{array}\right\} & \text{if } t+1 < t^g - 1 \\ \left\{\sum\limits_{l=0}^{t}(\beta^i)^t\pi^i(C_{\tilde{t}}^i, C_{\tilde{t}}^j) + (\beta^i)^{t^g-1}\pi^i(C^N, C^N)\right\} & \text{if } t+1 = t^g - 1 \end{cases}, \qquad (6)$$

because at $l = t^g$ the foreign firm enters the market and the two national firms shut down at $t = t^g$ (recall the remark 1, and the fact that the time period profits of the both firms for $l \geq t^g$ are $\pi^i(C^N, C^N, C^F) = 0$, as before). Now, under the alternative strategy $\tilde{s}^i = \{\tilde{s}_h^i\}$ given by $\tilde{s}_h^i = s_h(N)$ for all

$h \neq \tilde{h}$ and $\tilde{s}^i_{\tilde{h}} \neq s_{\tilde{h}}(N)$ —that is, $\{\tilde{s}^i_h\}_{h\in H}\big|_{\tilde{h}}\, \tilde{s}^i$ prescribes to adopt the new technology, independently of the technology used at t, after the history $\tilde{h}$, and to return to the national technology for all $h \in H|_{\tilde{h}}$— we will have

$$\Pi^i\left(\{\tilde{s}^i_h\}_{h\in H}\big|_{\tilde{h}}, \{s_h(N)\}_{h\in H}\big|_{\tilde{h}}\right)\big|_{\tilde{h}} =$$

$$\left\{\begin{array}{l} \left\{\begin{array}{l} \sum\limits_{l=0}^{t}(\beta^i)^l\pi^i(C^i_t, C^j_t) + (\beta^i)^{t+1}\pi^i(\tilde{s}^i_{\tilde{h}}, C^N) + \\ \sum\limits_{l=t+2}^{t^g-1}(\beta^i)^l\pi^i(C^N, C^N) \end{array}\right\} \text{if } t+1 < t^g - 1 \\ \left\{\sum\limits_{l=0}^{t}(\beta^i)^l\pi^i(C^i_t, C^j_t) + (\beta^i)^{t^g-1}\pi^i(\tilde{s}^i_{\tilde{h}}, C^N)\right\} \text{if } t+1 = t^g - 1 \end{array}\right. , \quad (7)$$

once again, because at $l = t^g$ the foreign firm enters the market (recall the remark 1, and the fact that the time period profits of the both firms for $l \geq t^g$ are $\pi^i(C^N, C^N, C^F) = 0$, as before). Now observe that, the cost associated to the action $\tilde{s}^i_{\tilde{h}}$, (denoted by C^i_{t+1}) is such that $C^i_{t+1} \geq (C^F + C^e_{t+1})$, because of the political costs, and $(C^F + C^e_{t+1}) > (C^F + C^e_{t^g}) > C^N$ because $t < t^g - 1$, $n > t^g$ (A3.1), and the economic costs are decreasing. Therefore we have $0 = \pi^i(C^i_{t+1}, C^N) < \pi^i(C^N, C^N)$ and, hence, $\Pi^i\left(\{\tilde{s}^i_h\}_{h\in H}, \{s_h(N)\}_{h\in H}\right)(\tilde{h}) < \Pi^i\left(\{s_h(N)\}_{h\in H}, \{s_h(N)\}_{h\in H}\right)(\tilde{h})$. This concludes the proof when $t < t^g - 1$.

Take now a history of the form $\tilde{h} = \left\{\left(a^I_l, a^P_l\right)\right\}^t_{l=0}$ for $t \geq t^g - 1$, and consider the corresponding vector of costs $\left\{\left(C^I_l, C^P_l\right)\right\}^t_{l=0}$. Firtst, we observe the following:

Remark 6 *Notice that a history* $\tilde{h} = \left\{\left(a^I_l, a^P_l\right)\right\}^t_{l=0}$ *may be such that the foreign technology is adopted at some period before* t *by a firm* $i \in \{I, P\}$*. Further, it may be such that* $t > n$ *and the foreign technology is adopted at* $t = 0$*. Nevertheless, since* $t^g < n$*, the costs corresponding to the periods from* t^g *to* $n-1$ *are not actually paid (the time-period profits of that firm are zero). Therefore, due to our assumptions (recall the remark 1), the payoff* $\Pi^i|_{\tilde{h}}$ *of any history* $h \in H|_{\tilde{h}}$ *that prescribes to adopt with the foreign technology will be such that the corresponding firm have to pay the costs of the foreign technology as it would not have paid anything.*

Then, in this last situation ($t \geq t^g - 1$), independently of the strategies of the firms, both firms shut down at $t = t^g$, given that they did not have enough time to install the new technology and, to install the new technology —completely— is the only way to survive at the moment the economy opens. Formally, we have $\Pi^i((\{s_h(N)\}_{h\in H}|_{\tilde{h}}, \{s_h(N)\}_{h\in H}|_{\tilde{h}}))|_{\tilde{h}} = \Pi^i\left(\{\tilde{s}^i_h\}_{h\in H}|_{\tilde{h}}, \{s_h(N)\}_{h\in H}|_{\tilde{h}}\right)|_{\tilde{h}} = \sum_{l=0}^{t^g-1}(\beta^i)^l\pi^i(C^i_t, C^j_t)$ for all $\tilde{s}^i = \{\tilde{s}^i_h\}$such that $\tilde{s}^i_h = s_h(N)$ for all $h \neq \tilde{h}$ and $\tilde{s}^i_{\tilde{h}} \neq s_{\tilde{h}}(N)$, due to the precedent remark.

The proof of 1.1 is done.

1.2 The proof of 1.2.

We will proceed as in 1.1. Take any history $\tilde{h} = \left\{(a^I_l, a^P_l)\right\}^t_{l=0}$ for $t < t^g - 1$. This history determines a vector of costs of the form $\left\{\left(C^I_l, C^P_l\right)\right\}^t_{l=0}$, as above. Consider now the payoffs $\Pi^i((\{s_h(N)\}_{h\in H}|_{\tilde{h}}, \{s_h(N)\}_{h\in H}|_{\tilde{h}}))|_{\tilde{h}}$ and $\Pi^i\left(\{\tilde{s}^i_h\}_{h\in H}|_{\tilde{h}}, \{s_h(N)\}_{h\in H}|_{\tilde{h}}\right)|_{\tilde{h}}$, which are given by (6) and (7) respectively, and $\{\tilde{s}^i_h\}_{h\in H}$ is given by $\tilde{s}^i_h = s_h(N)$ for all $h \neq \tilde{h}$ and $\tilde{s}^i_{\tilde{h}}$ prescribes to adopt the new technology independently of thecnology used at t. We have then to compare $\pi^i(C^i_{t+1}, C^N)$ with $\pi^i(C^N, C^N)$ (where C^i_{t+1} denotes the cost associated with the action $\tilde{s}^i_{\tilde{h}}$). Now, given that $t+1 < t^g$ and given $\tilde{s}^i_{\tilde{h}}$, we have that $C^i_{t+1} = C^e_0 + C^p_{t+1} + C^F$, since $a - (C^e_n + C^F) < C^p_t$ for all $t \leq t^g - 1$, which implies that no costs of the new technology were paid before $t+1$ (recall the remark 1). Given that the cost at $t+1$ is $C^e_0 + C^p_{t+1} + C^F$, we have once again $\pi^i(C^i_{t+1}, C^N) = 0$, since $a - (C^e_0 + C^F) < a - (C^e_n + C^F) < C^p_{t+1}$ (recall the lemma 1 and the fact that the economic costs are decreasing). Hence, $\pi^i(\tilde{s}^i_{\tilde{h}}, C^N) < \pi^i(C^N, C^N)$ and therefore $\Pi^i\left(\{\tilde{s}^i_h\}_{h\in H}|_{\tilde{h}}, \{s_h(N)\}_{h\in H}|_{\tilde{h}}\right)|_{\tilde{h}} < \Pi^i((\{s_h(N)\}_{h\in H}|_{\tilde{h}}, \{s_h(N)\}_{h\in H}|_{\tilde{h}}))|_{\tilde{h}}$.

Take, on the other hand, $\tilde{h} = \left\{(a^I_l, a^P_l)\right\}^t_{l=0}$ for $t \geq t^g - 1$ and, if $\left\{(C^I_l, C^P_l)\right\}^t_{l=0}$ is the associated sequence of costs to $\tilde{h}$, we will have that $\Pi^i((\{s_h(N)\}_{h\in H}|_{\tilde{h}}, \{s_h(N)\}_{h\in H}|_{\tilde{h}}))|_{\tilde{h}} = \Pi^i\left(\{\tilde{s}^i_h\}_{h\in H}|_{\tilde{h}}, \{s_h(N)\}_{h\in H}|_{\tilde{h}}\right)|_{\tilde{h}} = \sum_{l=0}^{t^g-1}(\beta^i)^l\pi^i(C^i_t, C^j_t)$ for all $\tilde{s}^i = \{\tilde{s}^i_h\}_{h\in H}$ such that $\tilde{s}^i_h = s_h(N)$ for all $h \neq \tilde{h}$ and $\tilde{s}^i_{\tilde{h}} \neq s_{\tilde{h}}(N)$. Indeed,
$\Pi^i((\{s_h(N)\}_{h\in H}|_{\tilde{h}}, \{s_h(N)\}_{h\in H}|_{\tilde{h}}))|_{\tilde{h}}$ is such that all the time-period Cournot profits after t are zero, since no costs of the new technology can be paid at $t < t^g$ (because $a - (C^e_n + C^F) < C^p_t$ for all $t \leq t^g - 1$) and, therefore, if $\left\{(C^I_l, C^P_l)\right\}^\infty_{l=t+1}$ is the associated sequence of costs to the profile of strategies $(\{s_h(N)\}_{h\in H}|_{\tilde{h}}, \{s_h(N)\}_{h\in H}|_{\tilde{h}})$ we will have $\pi^i(C^i_l, C^j_l, C^F) = 0$ for all $l \geq t^g$, due to that, independently of the fact that the new technology was or was not adopted before t^g, we will have $\frac{a-C^F}{2} \geq a - C^i_l$ for all

$l \geq t^g$ (because of the lemma 1, A2 and A3.1)). For the same reason, we have that $\Pi^i\left(\{\tilde{s}^i_h\}_{h\in H}\big|_{\tilde{h}}, \{s_h(N)\}_{h\in H}\big|_{\tilde{h}}\right)\big|_{\tilde{h}}$ is such that all the Cournot profits after t are zero, and therefore, $\Pi^i((\{s_h(N)\}_{h\in H}\big|_{\tilde{h}}, \{s_h(N)\}_{h\in H}\big|_{\tilde{h}}))\big|_{\tilde{h}} = \Pi^i\left(\{\tilde{s}^i_h\}_{h\in H}\big|_{\tilde{h}}, \{s_h(N)\}_{h\in H}\big|_{\tilde{h}}\right)\big|_{\tilde{h}}$ as asserted.

The proof of the theorem 1 is done. ■

2 Proof of the theorem 2.

2.1 Proof of 2.1

Consider $(s^I, s^P) = (\{s^I_h(N,2)\}_{h\in H}, \{s^P_h(T)\}_{h\in H})$ given by (4) and (5) respectively. Firts we will prove that $\{s^I_h(N,2)\}_{h\in H}$ is such that, for any $\tilde{h} \in H$, $\{s_h(N,2)\}_{h\in H}\big|_{\tilde{h}}$ is a best response to $\{s_h(T)\}_{h\in H}\big|_{\tilde{h}}$, provided that β^I is small enough.

Take $\tilde{h} = \emptyset$. Consider now the payoffs $\Pi^I((\{s_h(N,2)\}_{h\in H}\big|_{\tilde{h}}, \{s_h(T)\}_{h\in H}\big|_{\tilde{h}}))\big|_{\tilde{h}}$ and $\Pi^I\left(\{\tilde{s}^I_h\}_{h\in H}\Big|_{\tilde{h}}, \{s_h(T)\}_{h\in H}\big|_{\tilde{h}}\right)\Big|_{\tilde{h}}$, where $\tilde{s}^I = \{\tilde{s}^I_h\}_{h\in H}$ is such that $\tilde{s}^I_h = s_h(N,2)$ for all $h \neq \tilde{h}$ and $\tilde{s}^I_{\tilde{h}} \neq s_{\tilde{h}}(N,2)$. If $n > 1$, $\tilde{s}^I = \{\tilde{s}^I_h\}_{h\in H}$ prescribes to adopt the new technology at the beginning, but to adopt the national one for all $t \geq 1$. Hence

$$\Pi^I\left(\{\tilde{s}^I_h\}_{h\in H}\Big|_{\tilde{h}}, \{s_h(T)\}_{h\in H}\big|_{\tilde{h}}\right)\Big|_{\tilde{h}} =$$
$$\left\{\begin{array}{ll} \left\{\begin{array}{l} \pi^I(C^e_0 + C^p_0 + C^F, C^e_0 + C^p_0 + C^F) + \sum\limits_{l=1}^{n-1} (\beta^I)^l \pi^I(C^N, C^e_l + C^F) \\ \sum\limits_{l=n}^{t^g-1} (\beta^i)^l \pi^i(C^N, C^e_n + C^F) \end{array}\right\} & \text{if } n \leq t^g - 1 \\ \left\{\pi^I(C^e_0 + C^p_0 + C^F, C^e_0 + C^p_0 + C^F) + \sum\limits_{l=1}^{n-1} (\beta^I)^l \pi^I(C^N, C^e_l + C^F)\right\} & \text{if } n = t^g \end{array}\right. . \tag{8}$$

(once again, because the Cournot profits for all $t \geq t^g$ are $\pi^I(C^N, C^e_n + C^F, C^F) = 0$, due to A2, A3 and the lemma 1) and,

$$\Pi^I((\{s_h(N,2)\}_{h\in H}\big|_{\tilde{h}}, \{s_h(T)\}_{h\in H}\big|_{\tilde{h}}))\big|_{\tilde{h}} =$$
$$\begin{cases} \left\{\begin{array}{l} \pi^I(C^N, C_0^e + C_0^p + C^F) + \sum_{l=1}^{n-1}(\beta^I)^l \pi^I(C^N, C_l^e + C^F) \\ \sum_{l=n}^{t^g-1}(\beta^i)^l \pi^i(C^N, C_n^e + C^F) \end{array}\right\} & \text{if } n \le t^g - 1 \\ \left\{\pi^I(C^N, C_0^e + C_0^p + C^F) + \sum_{l=1}^{n-1}(\beta^I)^l \pi^I(C^N, C_l^e + C^F)\right\} & \text{if } n = t^g \end{cases}, \tag{9}$$

for the same reason as in (8).

Clearly, $\Pi^I(\{\tilde{s}_h^I\}_{h\in H}\big|_{\tilde{h}}, \{s_h(T)\}_{h\in H}\big|_{\tilde{h}}\big|_{\tilde{h}}) < \Pi^I((\{s_h(N,2)\}_{h\in H}\big|_{\tilde{h}}, \{s_h(T)\}_{h\in H}\big|_{\tilde{h}}))\big|_{\tilde{h}}$, since $\pi^I(C_0^e + C_0^p + C^F, C_0^e + C_0^p + C^F) < \pi^I(C^N, C_0^e + C_0^p + C^F)$ (due to A3.1, A3.2 and the lemma 1).

Now, if $n = 1$, $\tilde{s}^I = \{\tilde{s}_h^I\}_{h\in H}$ prescribes to install the new technology at the beginning. Hence,

$$\Pi^I\left(\{\tilde{s}_h^I\}_{h\in H}\big|_{\tilde{h}}, \{s_h(T)\}_{h\in H}\big|_{\tilde{h}}\right)\Big|_{\tilde{h}} =$$
$$\begin{cases} \left\{\begin{array}{l} \pi^I(C_0^e + C_0^p + C^F, C_0^e + C_0^p + C^F) + \sum_{l=1}^{t^g-1}(\beta^i)^l \pi^I(C_1^e + C^F, C_1^e + C^F) + \\ \sum_{l=t^g}^{\infty}(\beta^I)^l \pi^I(C_1^e + C^F, C_1^e + C^F, C^F) \end{array}\right\} & \text{if } t^g > 1 \\ \left\{\pi^I(C_0^e + C_0^p + C^F, C_0^e + C_0^p + C^F) + \sum_{l=1}^{\infty}(\beta^I)^l \pi^I(C_1^e + C^F, C_1^e + C^F, C^F)\right\} & \text{if } t^g = 1 \end{cases}$$

and

$$\Pi^I((\{s_h(N,2)\}_{h\in H}\big|_{\tilde{h}}, \{s_h(T)\}_{h\in H}\big|_{\tilde{h}}))\big|_{\tilde{h}} =$$
$$\begin{cases} \left\{\pi^I(C^N, C_0^e + C_0^p + C^F) + \sum_{l=1}^{t^g-1}(\beta^i)^l \pi^i(C^N, C_l^e + C^F)\right\} & \text{if } t^g > 1 \\ \left\{\pi^I(C^N, C_0^e + C_0^p + C^F)\right\} \text{ if } t^g = 1. \end{cases}$$

(the same justification as in (8) applies for both $t^g = 1$ and $t^g > 1$).

Now, observe that, either $t^g = 1$ or $t^g > 1$, we have

$$\lim_{\beta^I \to 0} \Pi^I((\{s_h(N,2)\}_{h\in H}\big|_{\tilde{h}}, \{s_h(T)\}_{h\in H}\big|_{\tilde{h}}))\big|_{\tilde{h}} - \Pi^I\left(\{\tilde{s}_h^I\}_{h\in H}\big|_{\tilde{h}}, \{s_h(T)\}_{h\in H}\big|_{\tilde{h}}\right)\Big|_{\tilde{h}} =$$

$\pi^I(C^N, C_0^e + C_0^p + C^F) - \pi^I(C_0^e + C_0^p + C^F, C_0^e + C_0^p + C^F) > 0$ (due to A3.1 and A3.2). Therefore, we have proven the following statement:

$$\left.\begin{array}{l}\text{If } \tilde{h} = \emptyset\text{, then there exist } \beta_1^I \text{ such that, if } \beta^I \ < \beta_1^I\text{, therefore,} \\ \Pi^I((\{s_h(N,2)\}_{h\in H}\big|_{\tilde{h}}, \{s_h(T)\}_{h\in H}\big|_{\tilde{h}}))\big|_{\tilde{h}} - \\ \Pi^I\left(\left\{\tilde{s}_h^I\right\}_{h\in H}\Big|_{\tilde{h}}, \{s_h(T)\}_{h\in H}\big|_{\tilde{h}}\right)\Big|_{\tilde{h}} > 0 \text{ for all } \tilde{s}^I = \left\{\tilde{s}_h^I\right\}_{h\in H} \\ \text{such that } \tilde{s}_h^I = s_h(N,2) \text{ for all} h \neq \tilde{h} \text{ and } \tilde{s}_{\tilde{h}}^I \neq s_{\tilde{h}}(N,2).\end{array}\right\} \quad (10)$$

Take $\tilde{h} = \left\{(a_l^I, a_l^P)\right\}_{l=0}^t \in H_0^I$ with $t < n-1$ (we suposse, for this case, that $n > 1$, otherwise there is nothing to prove). There are two cases, $t < n-2$ and $t = n-2$. If $t < n-2$, then $\{s_h(N,2)\}_{h\in H}$ prescribes to adopt the old technology for all $l \geq t+1$. On the other hand, if $\tilde{s}^I = \left\{\tilde{s}_h^I\right\}_{h\in H}$ is such that $\tilde{s}_h^I = s_h(N,2)$ for all $h \neq \tilde{h}$ and $\tilde{s}_{\tilde{h}}^I \neq s_{\tilde{h}}(N,2)$, then it prescribes to continue with the new technology at $t+1$, but to adopt the old one for all $l \geq t+2$. Consequently, denoting by $\left\{C_l^P\right\}_{l=t+1}^{\infty}$ the corresponding sequences of costs of the patient firm (given $\tilde{h}$ and $\{s_h(T)\}_{h\in H}$),[6] we have that

$$\begin{array}{c}\Pi^I((\{s_h(N,2)\}_{h\in H}\big|_{\tilde{h}}, \{s_h(T)\}_{h\in H}\big|_{\tilde{h}}))\big|_{\tilde{h}} = \\ \pi^I(C_0^e + C_0^p + C^F, C_0^P) + \sum_{l=1}^{t}(\beta^I)^l \pi^I(C_l^e + C^F, C_l^P) + \\ \sum_{l=t+1}^{n-1}(\beta^I)^l \pi^I(C^N, C_l^P) + \sum_{l=n}^{t^g-1}(\beta^I)^l \pi^I(C^N, C_l^P)\end{array}$$

(the same justification as in (8) applies), and

$$\begin{array}{c}\Pi^I\left(\left\{\tilde{s}_h^I\right\}_{h\in H}\Big|_{\tilde{h}}, \{s_h(T)\}_{h\in H}\big|_{\tilde{h}}\right)\Big|_{\tilde{h}} = \\ \pi^I(C_0^e + C_0^p + C^F, C_0^P) + \sum_{l=1}^{t}(\beta^I)^l \pi^I(C_l^e + C^F, C_l^P) + \\ (\beta^I)^{t+1}\pi^I(C_{t+1}^e + C^F, C_l^P) + \sum_{l=t+2}^{n-1}(\beta^I)^l \pi^I(C^N, C_l^P) + \\ \sum_{l=n}^{t^g-1}(\beta^I)^l \pi^I(C^N, C_l^P)\end{array}$$

(one more time, the same justification as in (8) applies). Now, observe that the diference $\Pi^I((\{s_h(N,2)\}_{h\in H}\big|_{\tilde{h}}, \{s_h(T)\}_{h\in H}\big|_{\tilde{h}}))\big|_{\tilde{h}} -$

[6] Note that the strategy of a firm $i \in \{I, P\}$ is only defined in terms of the sets H_0^i and H_1^i. Therefore, the sequence of costs of a strategy, given a history $h \in H$, of a firm, doos not change if we change the strategy of the other firm.

$\Pi^I\left(\left\{\tilde{s}^I_h\right\}_{h\in H}\Big|_{\tilde{h}}, \{s_h(T)\}_{h\in H}|_{\tilde{h}}\right)\Big|_{\tilde{h}}$ is equal to $(\beta^I)^{t+1}(\pi^I(C^N, C^P_{t+1}) - \pi^I(C^e_{t+1} + C^F, C^P_{t+1})) > 0$, due to that $t+1 < n-1$, A3.1 and the lemma 1. The case when $t < n-2$ is concluded.

Now suppose that $t = n-2$. Again, $\{s_h(N,2)\}_{h\in H}$ prescribes to use the old technology for all $l \geq t+1$. On the other hand, if $\tilde{s}^I = \left\{\tilde{s}^I_h\right\}_{h\in H}$ is such that $\tilde{s}^I_h = s_h(N,2)$ for all $h \neq \tilde{h}$ and $\tilde{s}^I_{\tilde{h}} \neq s_{\tilde{h}}(N,2)$, then it prescribes to adopt the new technolgy for all $l \geq t+1$. Ergo, denoting by $\left\{C^P_l\right\}^{\infty}_{l=t+1}$ the corresponding sequences of costs of the patient firm (given $\tilde{h}$ and $\{s_h(T)\}_{h\in H}$), we have that

$$\Pi^I\left(\left\{\tilde{s}^I_h\right\}_{h\in H}\Big|_{\tilde{h}}, \{s_h(T)\}_{h\in H}|_{\tilde{h}}\right)\Big|_{\tilde{h}} =$$
$$\pi^I(C^e_0 + C^p_0 + C^F, C^P_0) + \sum_{l=1}^{n-1}(\beta^I)^l\pi^I(C^e_l + C^F, C^P_l) +$$
$$\begin{cases} \left\{\sum_{l=n}^{t^g-1}(\beta^I)^l\pi^I(C^e_n + C^F, C^P_l) + \sum_{l=t^g}^{\infty}(\beta^I)^l\pi^I(C^e_n + C^F, C^P_l, C^F)\right\} \text{ if } n \leq t^g - 1 \\ \left\{\sum_{l=t^g}^{\infty}(\beta^I)^l\pi^I(C^e_n + C^F, C^P_l, C^F)\right\} \text{ if } n = t^g \end{cases},$$

and

$$\Pi^I((\{s_h(N,2)\}_{h\in H}|_{\tilde{h}}, \{s_h(T)\}_{h\in H}|_{\tilde{h}}))|_{\tilde{h}} =$$
$$\pi^I(C^e_0 + C^p_0 + C^F, C^P_0) + \sum_{l=1}^{n-2}(\beta^I)^l\pi^I(C^e_l + C^F, C^P_l) +$$
$$(\beta^I)^{n-1}\pi^I(C^N C^P_l,) + \sum_{l=n}^{t^g-1}(\beta^I)^l\pi^I(C^N, C^P_l)$$

(one more time, the same justification as in (8) applies).

Then, the diference $\Pi^I((\{s_h(N,2)\}_{h\in H}|_{\tilde{h}}, \{s_h(T)\}_{h\in H}|_{\tilde{h}}))|_{\tilde{h}} -$ $\Pi^I\left(\left\{\tilde{s}^I_h\right\}_{h\in H}\Big|_{\tilde{h}}, \{s_h(T)\}_{h\in H}|_{\tilde{h}}\right)\Big|_{\tilde{h}}$ is equal to $\left(\beta^I\right)^{n-1}\Lambda(H^I_0)$, where $\Lambda(H^I_0) =$ $\left\{\pi^I(C^N, C^P_{n-1}) - \pi^I(C^e_{n-1} + C^F, C^P_{n-1})\right\} +$

$$\left(\beta^I\right)^{1-n}\left\{\begin{array}{c} \sum_{l=n}^{t^g-1}(\beta^I)^l\left[\pi^I(C^N, C^P_l)\right] - \\ \begin{cases} \left\{\begin{array}{c} \sum_{l=n}^{t^g-1}(\beta^I)^l\pi^I(C^e_n + C^F, C^P_l) + \\ \sum_{l=t^g}^{\infty}(\beta^I)^l\pi^I(C^e_n + C^F, C^P_l, C^F) \end{array}\right\} \text{ if } n \leq t^g - 1 \\ \left\{\sum_{l=t^g}^{\infty}(\beta^I)^l\pi^I(C^e_n + C^F, C^P_l, C^F)\right\} \text{ if } n = t^g \end{cases} \end{array}\right\}.$$

Now, $\lim_{\beta^I \to 0} \Lambda(H_0^I) = \left\{\pi^I(C^N, C_{n-1}^P) - \pi^I(C_{n-1}^e + C^F, C_{n-1}^P)\right\} > 0$, due to A3.1, A3.2 and the lemma 1. The case when $t < n-2$ is concluded.

Take $\tilde{h} = \left\{(a_l^I, a_l^P)\right\}_{l=0}^t \in H_0^I$ with $t \geq n-1$, and $\tilde{s}^I = \left\{\tilde{s}_h^I\right\}_{h\in H}$such that $\tilde{s}_h^I = s_h(N,2)$ for all $h \neq \tilde{h}$ and $\tilde{s}_{\tilde{h}}^I \neq s_{\tilde{h}}(N,2)$. In this case, $\left.\{s_h(N,2)\}_{h\in H}\right|_{\tilde{h}}$ prescribes to continue with the new technology for all $l \geq t+1$ and $\left.\left\{\tilde{s}_h^I\right\}_{h\in H}\right|_{\tilde{h}}$ prescribes to adopt the national technology for all $l \geq t+1$. Consequently, if $\left\{(C_l^I, C_l^P)\right\}_{l=0}^t$ denotes the sequence of costs associated to $\tilde{h}$, and denoting by $\left\{C_l^P\right\}_{l=t+1}^{\infty}$ the corresponding sequences of costs of the patient firm (given $\tilde{h}$ and $\{s_h(T)\}_{h\in H}$), we will have

$$\Pi^I((\{s_h(N,2)\}_{h\in H}|_{\tilde{h}}, \{s_h(T)\}_{h\in H}|_{\tilde{h}}))|_{\tilde{h}} = \sum_{l=0}^{t}(\beta^I)^l \pi^I((C_l^I, C_l^P)) +$$
$$\begin{cases} \sum\limits_{l=t+1}^{t^g-1}(\beta^I)^l \pi^I(C_n^e + C^F, C_l^P) + \sum\limits_{l=t^g}^{\infty}(\beta^I)^l \pi^I(C_n^e + C^F, C_l^P) \text{ if } t+1 \leq t^g - 1 \\ \sum\limits_{l=t+1}^{\infty}(\beta^I)^l \pi^I(C_n^e + C^F, C_l^P, C^F) \text{ if } t+1 > t^g - 1 \end{cases}$$

$$\Pi^I\left(\left.\left\{\tilde{s}_h^I\right\}_{h\in H}\right|_{\tilde{h}}, \{s_h(T)\}_{h\in H}|_{\tilde{h}}\right)\Big|_{\tilde{h}} =$$
$$\sum_{l=0}^{t}(\beta^I)^l \pi^I((C_l^I, C_l^P)) + \begin{cases} \sum\limits_{l=t+1}^{t^g-1}(\beta^I)^l \pi^I(C^N, C_l^P) \text{ if } t+1 \leq t^g - 1 \\ 0 \text{ if } t+1 > t^g - 1 \end{cases}.$$

Now, we have that $\pi^I(C_n^e + C^F, C_n^P) > \pi^I(C^N, C_n^P)$, since A2 and A3.3 imply that $C_n^e + C^F < C^N$. This concludes the case when $t \geq n-1$.

Then we have proven the following statement

$$\left.\begin{array}{l} \text{If } \tilde{h} = \left\{(a_l^I, a_l^P)\right\}_{l=0}^t \in H_0^I, \text{ then there exist } \beta_2^I \text{ such that,} \\ \text{if } \beta^I < \beta_2^I, \text{ therefore, } \Pi^I((\{s_h(N,2)\}_{h\in H}|_{\tilde{h}}, \{s_h(T)\}_{h\in H}|_{\tilde{h}}))|_{\tilde{h}} - \\ \Pi^I\left(\left.\left\{\tilde{s}_h^I\right\}_{h\in H}\right|_{\tilde{h}}, \{s_h(T)\}_{h\in H}|_{\tilde{h}}\right)\Big|_{\tilde{h}} > 0 \text{ for all } \tilde{s}^I = \left\{\tilde{s}_h^I\right\}_{h\in H} \\ \text{such that } \tilde{s}_h^I = s_h(N,2) \text{ for all } h \neq \tilde{h} \text{ and } \tilde{s}_{\tilde{h}}^I \neq s_{\tilde{h}}(N,2). \end{array}\right\} \quad (11)$$

The same reasoning can be used to analyze the the cases where $\tilde{h} = \left\{(a_l^I, a_l^P)\right\}_{l=0}^t \in H_1^I$ with $t \geq l_1 + n - 1$ and $t < l_1 + n - 1$. Therefore, we have the following statement proven

$$\left.\begin{array}{l} \text{If } \tilde{h} = \left\{(a_l^I, a_l^P)\right\}_{l=0}^{t} \in H_1^I, \text{ then there exist } \beta_3^I \text{ such that,} \\ \text{if } \beta^I < \beta_2^I, \text{ therefore, } \Pi^I((\{s_h(N,2)\}_{h\in H}\big|_{\tilde{h}}, \{s_h(T)\}_{h\in H}\big|_{\tilde{h}}))\big|_{\tilde{h}} - \\ \Pi^I\left(\left\{\tilde{s}_h^I\right\}_{h\in H}\Big|_{\tilde{h}}, \{s_h(T)\}_{h\in H}\big|_{\tilde{h}}\right)\Big|_{\tilde{h}} > 0 \text{ for all } \tilde{s}^I = \left\{\tilde{s}_h^I\right\}_{h\in H} \\ \text{such that } \tilde{s}_h^I = s_h(N,2) \text{ for all } h \neq \tilde{h} \text{ and } \tilde{s}_{\tilde{h}}^I \neq s_{\tilde{h}}(N,2). \end{array}\right\} \quad (12)$$

Take $h \neq \emptyset$ such that $h = \left\{(a_l^I, a_l^P)\right\}_{l=0}^{t} \notin H_0^I \cup H_1^I$ and $C_t^I \neq C^N$ and $\tilde{s}^I = \left\{\tilde{s}_h^I\right\}_{h\in H}$such that $\tilde{s}_h^I = s_h(N,2)$ for all $h \neq \tilde{h}$ and $\tilde{s}_{\tilde{h}}^I \neq s_{\tilde{h}}(N,2)$. Therefore, $\{s_h(N,2)\}_{h\in H}\big|_{\tilde{h}}$ prescribes to adopt the national technology for all $l \geq t+1$ and $\left\{\tilde{s}_h^I\right\}_{h\in H}\Big|_{\tilde{h}}$ prescribes to adopt the foreign technology at $t+1$, but to adopt the national technology for all $l \geq t+2$. In this case, denoting by $\left\{C_l^P\right\}_{l=t+1}^{\infty}$ the corresponding sequences of costs of the patient firm (given $\tilde{h}$ and $\{s_h(T)\}_{h\in H})$), we have $\Pi^I((\{s_h(N,2)\}_{h\in H}\big|_{\tilde{h}}, \{s_h(T)\}_{h\in H}\big|_{\tilde{h}}))\big|_{\tilde{h}} -$ $\Pi^I\left(\left\{\tilde{s}_h^I\right\}_{h\in H}\Big|_{\tilde{h}}, \{s_h(T)\}_{h\in H}\big|_{\tilde{h}}\right)\Big|_{\tilde{h}} =$ $\begin{cases} (\beta^I)^{t+1}\left[\pi^I(C^N, C_{t+1}^P) - \pi^I(C_0^e + C_{t+1}^p, C_{t+1}^P)\right] \text{ if } t+1 \leq t^g - 1 \\ 0 \text{ if } t+1 > t^g - 1 \end{cases}$ because, if $t+1 \leq t^g - 1$ the corresponding sequences of costs difer only at $t+1$ and, if $t+1 > t^g - 1$, since the new technology neither was installed from the beginning nor can be finished to install before t^g which implies, due to the remark 1 and A2, all the Cournot profits after $t+1$ are null. Therefore, the following statement is proven

$$\left.\begin{array}{l} \text{If } h \neq \emptyset \text{ and } h = \left\{(a_l^I, a_l^P)\right\}_{l=0}^{t} \notin H_0^I \cup H_1^I \text{ and } C_t^I \neq C^N, \\ \text{therefore, } \Pi^I((\{s_h(N,2)\}_{h\in H}\big|_{\tilde{h}}, \{s_h(T)\}_{h\in H}\big|_{\tilde{h}}))\big|_{\tilde{h}} - \\ \Pi^I\left(\left\{\tilde{s}_h^I\right\}_{h\in H}\Big|_{\tilde{h}}, \{s_h(T)\}_{h\in H}\big|_{\tilde{h}}\right)\Big|_{\tilde{h}} > 0 \text{ for all } \tilde{s}^I = \left\{\tilde{s}_h^I\right\}_{h\in H} \\ \text{such that } \tilde{s}_h^I = s_h(N,2) \text{ for all } h \neq \tilde{h} \text{ and } \tilde{s}_{\tilde{h}}^I \neq s_{\tilde{h}}(N,2). \end{array}\right\} \quad (13)$$

A similar reasoning can be used for the case where $h \neq \emptyset$ such that $h = \left\{(a_l^I, a_l^P)\right\}_{l=0}^{t} \notin H_0^I \cup H_1^I$ and $C_t^I = C^N$ and $\tilde{s}^I = \left\{\tilde{s}_h^I\right\}_{h\in H}$such that $\tilde{s}_h^I = s_h(N,2)$ for all $h \neq \tilde{h}$ and $\tilde{s}_{\tilde{h}}^I \neq s_{\tilde{h}}(N,2)$. Therefore, the following statement is proven

$$\left.\begin{array}{l}\text{If } h \neq \emptyset \text{ and } h = \left\{(a_l^I, a_l^P)\right\}_{l=0}^{t} \notin H_0^I \cup H_1^I \text{ and } C_t^I = C^N, \\ \text{therefore, } \Pi^I((\{s_h(N,2)\}_{h\in H}\big|_{\tilde{h}}, \{s_h(T)\}_{h\in H}\big|_{\tilde{h}}))\big|_{\tilde{h}} - \\ \Pi^I\left(\left\{\tilde{s}_h^I\right\}_{h\in H}\Big|_{\tilde{h}}, \{s_h(T)\}_{h\in H}\big|_{\tilde{h}}\right)\Big|_{\tilde{h}} > 0 \text{ for all } \tilde{s}^I = \left\{\tilde{s}_h^I\right\}_{h\in H} \\ \text{such that } \tilde{s}_h^I = s_h(N,2) \text{ for all } h \neq \tilde{h} \text{ and } \tilde{s}_{\tilde{h}}^I \neq s_{\tilde{h}}(N,2).\end{array}\right\} \tag{14}$$

Consequently, we the following statement is proven

$$\left.\begin{array}{l}\text{There exist } \tilde{\beta}^I \text{ such that, if } \beta^I < \tilde{\beta}^I, \text{ if } h \in H, \text{ therefore,} \\ \text{therefore, } \Pi^I((\{s_h(N,2)\}_{h\in H}\big|_{\tilde{h}}, \{s_h(T)\}_{h\in H}\big|_{\tilde{h}}))\big|_{\tilde{h}} - \\ \Pi^I\left(\left\{\tilde{s}_h^I\right\}_{h\in H}\Big|_{\tilde{h}}, \{s_h(T)\}_{h\in H}\big|_{\tilde{h}}\right)\Big|_{\tilde{h}} > 0 \text{ for all } \tilde{s}^I = \left\{\tilde{s}_h^I\right\}_{h\in H} \\ \text{such that } \tilde{s}_h^I = s_h(N,2) \text{ for all } h \neq \tilde{h} \text{ and } \tilde{s}_{\tilde{h}}^I \neq s_{\tilde{h}}(N,2).\end{array}\right\} \tag{15}$$

The proof follows at once from (10), (11), (12), (13) and (14).

An analogous reasoning can be used to prove the following statement

$$\left.\begin{array}{l}\text{There exist } \tilde{\beta}^P \text{ such that, if } \tilde{\beta}^P < \beta^P, \text{ if } h \in H, \text{ therefore,} \\ \text{therefore, } \Pi P((\{s_h(T)\}_{h\in H}\big|_{\tilde{h}}), \{s_h(N,2)\}_{h\in H}\big|_{\tilde{h}})\big|_{\tilde{h}} - \\ \Pi^I\left(\left\{\tilde{s}_h^I\right\}_{h\in H}\Big|_{\tilde{h}}, \{s_h(N,2)\}_{h\in H}\big|_{\tilde{h}}\right)\Big|_{\tilde{h}} > 0 \text{ for all } \tilde{s}^P = \left\{\tilde{s}_h^P\right\}_{h\in H} \\ \text{such that } \tilde{s}_h^P = s_h(T) \text{ for all } h \neq \tilde{h} \text{ and } \tilde{s}_{\tilde{h}}^I \neq s_{\tilde{h}}(T).\end{array}\right\} \tag{16}$$

Therefore, in virtue of (15) and (16), the proff of (2.1) in the theorem 2 is finished.

Remark 7 *Notice that, as mentioned in the note 5, the strategies* $s^I = \{s_h(N,2)\}_{h\in H}$ *and* $s^P = \{s_h(T)\}_{h\in H}$ *are defined in terms of the sets* H_0^I *and* H_1^I*, and* H_0^P *and* H_1^P *respectively. Therefore, the same arguments can be used to pove (2.2) and (2.3) in the theorem 2.*

The proof the the theorem 2 is concluded.

6 References

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